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ON THE ORIGIN OF DOUBLE MONSTROSITY. By  
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LIKE all the other great teratological problems, though to a higher degree than any other, the subject of double monstrosity has been a fruitful source of dispute, which in this case has been between the supporters of the two great rival theories—that of original duplicity with subsequent fusion, on the one hand, and that of original unity followed by fission, on the other.

That the latter is the correct explanation, appears to me to be rendered more certain by each successive observation which becomes known. Without discussing the *pros* and *cons* of either side, which would be foreign to the intention of this paper, it may be permitted to refer to the most recent evidence in favour of the fission theory.

In a paper on “Birds with Supernumerary Legs,”<sup>1</sup> Professor Cleland has laid down the law, “that in cases of supernumerary legs connected with the sacrum or perineum, the legs developed as the proper legs of the animal belong originally to two different pelvises, being the right limb of a right pelvis, and the left limb of a left pelvis, and that in these circumstances the appended limbs may be two, or one of the two may be suppressed, or there may be a composite limb formed by the undivided blastema for two adjacent limbs of two pelvises.” In other words, the smaller pair of limbs are not, as appears to have been taken for granted, fellows, and superadded to the functional, being themselves also a pair, but the true pairs are formed severally of a functional and a non-functional limb.

When the paper above alluded to was written, no recorded human case in all respects bore out the theory put forward, though some did so in a minor degree. Within the last few

<sup>1</sup> *Proc. Phil. Soc.*, Glasgow, 1886; and *Memoirs and Memoranda in Anatomy*, vol. i., 1889. *N.B.*—Professor Cleland informs me that, by a clerical error, the words referring to the sides have been reversed. The quotation above is corrected.

months, however, one has been placed on record which completely bears out Professor Cleland's views.

In the *American Journal of Obstetrics*,<sup>1</sup> Dr Wells gives an account of a female double monster, whose case has attracted some attention in the medical journals. She possesses "a well-formed single body, with normal upper extremities, which below the waist broadens out, having two umbilici, and bifurcating at the pelvis, where there are four lower limbs, all of which spring from the same horizontal and vertical plane. The spinal column divides at the third lumbar vertebra, the two pelves being fused by the junction of their respective ilia. There are two pelvic arches supplying the four limbs, two pubes, two montes Veneris, two perfect sets of external and internal female generative organs, two bladders, two ani, and two lower intestines. The outer limbs on which the woman walks are well developed, though the foot of the right is in a condition of equino-varus. The inner limbs are smaller, atrophied from disuse, and below the knee very rudimentary."

Here, then, as in the cases of the birds, the true pairs are not the functional and the non-functional limbs, but a functional with a non-functional on either side.

Cases such as these, viewed in the light which Professor Cleland has thrown upon them, appear to me to be unexplainable upon any other hypothesis than that of fission. Assuming that this is the true explanation, the object of this paper is to inquire whether recent biological studies give any assistance in the search for the cause of this abnormal division.

At the outset, it may be said that the known facts appear to point to the conclusion that fission, at least in cases of complete or nearly complete duplicity, must take place at an extremely early period, if not at the very earliest. Lists of observed double forms, such as have been given by Rauber,<sup>2</sup> Reichert,<sup>3</sup> and Gerlach,<sup>4</sup> include several which have been met with at very early stages of development, and to these may be added the most recent observation by Burckhardt,<sup>5</sup> of two primitive streaks,

<sup>1</sup> Vol. xxi. p. 1265.

<sup>2</sup> Virchow's *Archiv*, Bd. lxxi. s. 133.

<sup>3</sup> *Arch. für Anat. u. Phys.*, 1864, s. 744.

<sup>4</sup> *Die Entstehungsweise der Doppelmissbildungen*, Stuttgart, 1882.

<sup>5</sup> *Arch. f. Anat. u. Entwick.*, s. 431, 1888.

lying on a single area pellucida, in an egg which had undergone nineteen hours incubation. We may, however, I think, date the time of fission even further back than in any of these cases. Pflüger<sup>1</sup> and Roux<sup>2</sup> have shown that, in *Rana*, the first line of fission divides the embryo into two halves, a right and a left, and that the second, which is excentric, cuts off a larger head segment from a smaller for the tail. That the order in which these lines appear may be variable is admitted by Roux, and this point is confirmed by Rauber's<sup>3</sup> observations on the Axolotl, and those of Goette<sup>4</sup> on Worms; but the important fact is admitted by all these observers, that the early lines of segmentation divide the embryo into different regions. To quote Roux,<sup>5</sup> "the first division of the ovum stands in a strict relation to the chief axis of the body. One line of fission marks out the median plane, another the dorsal and ventral aspects, and another the anterior and posterior portions of the body. With these divisions of the axis go also the corresponding potentialities, dorsal and ventral, oral and aboral, which are differentiated from one another, and deposited on both sides in their proper positions." These observations have been confirmed for other species by Ch. Julin, E. van Beneden, and Nuel.<sup>6</sup>

That occurrences of a parallel nature take place in plants is a strong proof of the law which the foregoing observations, with others yet to be detailed, point to, namely, that the different lines of segmentation cut off from one another cells, or groups of cells, with different potentialities. Dealing with the second or asexual generation of the Fern, Goebel<sup>7</sup> states that the first set of octants form the primitive stem, the primary root, and one or two leaves, also the organ of suction or foot which conveys nutriment from the prothallium to the embryo. The orientation of these is regular:—"The rudiments of the apex of the

<sup>1</sup> *Arch. f. d. ges. Phys.*, Bd. xxxi. s. 311; Bd. xxxii. s. 1; *Virch. u. Hirsch Jahresb.*, i. 91, 1883.

<sup>2</sup> *Ueb. die bestimmung der Hauptrichtungen der Froschembryo.*

<sup>3</sup> *Ber. der naturf. Gesellsch. zu Leipzig*, 1884; *V. u. H. Jahresb.*, i. 77, 1884.

<sup>4</sup> *Abhand. zur Entwick. der Thiere*, Hft. i. s. 7; Hft. ii. s. 56 (*vide* Roux).

<sup>5</sup> *Op. cit.*, p. 44.

<sup>6</sup> Roux, *op. cit.*, p. 6.

<sup>7</sup> *Classif. and Special Morphology of Plants*, Eng. Trans., p. 204.

stem and of the foot lie on the side of the embryo, which is towards the under side of the prothallium, and are therefore turned upwards; the cotyledon and the rudiment of the foot on the side towards the neck of the archegonium, and therefore directed downwards." Again, as in animals, the order in which the septa, constituting the octants, appear is variable, but the parts formed from them are constant. Thus, of the two anterior upper octants one becomes the growing point of the stem, the other undergoes, as a rule, no further differentiation; the two anterior lower octants develop into the first leaf, the cotyledon; the two posterior upper octants form the foot, and one of the two posterior and lower ones forms the root, while the other does not usually develop like the rest."

Roux's<sup>1</sup> most recent work is of further interest in connection with this subject. After the formation of the first line of fission in the ova of *Rana esculenta*, he destroyed one hemisphere with a fine heated needle. Of the ova thus treated, some died, some developed a little further and then also perished, whilst 20 per cent. lived to proceed to more advanced embryological stages. In these the uninjured hemisphere might obviously have developed either into a small but complete embryo, or into a half embryo. The latter, as a matter of fact, was what occurred, and the result, if the first segmentation line had been in the long axis, was to produce lateral hemi-embryos, if in the transverse anterior or posterior hemi-embryos. Similarly, destruction of one of the segments, after four had been formed, led to the production of three-quarter embryos. How far development might have proceeded is an open question, since the oldest artificially killed embryo showed no signs of death, but the observations were carried far enough to establish the facts stated above. From this it follows that the first line of fission separates from one another cells which have different morphological values, since one forms the right the other the left side of the body, or the one the head, the other the tail end, as the case may be. If this be true, then the fission which leads to the formation of duplicity must be something (1) different in its nature, and (2) antecedent to the fission which leads to normal

<sup>1</sup> "Ueb. die künstliche Hervorbringung halberembryonen, u. s. w.," Virchow's *Arch.*, Bd. cxiv. Hft. i. s. 113; and Hft. ii. s. 246.



development. In other words, in cases of duplicity a fission of multiplication precedes the fission of formation. This conclusion would throw back the period of fission to an earlier date than has been fixed by most writers, even the most recent, as for example Born,<sup>1</sup> but I am inclined to believe that it is the most legitimate deduction from the facts detailed.

If fission, then, occurs as the first incident in the development of the double form, it remains to inquire what cause, if any, can be assigned for its occurrence.

Professor Cleland has, in several papers, recently stated his belief that irritation of some kind is this cause. Thus, he says,<sup>2</sup> "every vertebrate animal has, at an early period of its existence, a latent capacity of splitting up indefinitely;" and<sup>3</sup> "double monstrosity consists in the outbreak of proliferation at an unusual period, with consequences dependent on the greater or less perfection of the process, and this outbreak we may fairly impute to irritation." Finally,<sup>4</sup> "over-stimulation, when it occurs soon after impregnation of the ovum, leads to fissiparous division of the germinal mass, resulting in two embryos; at a later period, or carried to a slighter extent, it will cause partial division." In this opinion he agrees with other observers, amongst whom may be mentioned Knoch,<sup>5</sup> who, from his experiments on ova developed in still and running water, the latter affording the greater number of double forms, believed that the agitation was the causative irritation.

Ahlfeld<sup>6</sup> attributes the cleavage to "a faulty relation between zona pellucida and embryo," and his reasons will be found in his well-known work. Kidd<sup>7</sup> formulated the idea which others have held, and which has been criticised by Ahlfeld, that the cause is to be found in a superabundance of formative material. "The formative germ," he says, "is likely to suffer

<sup>1</sup> *Ueb. die Furch. des Eies bei Doppelmissbild*, *Bresl. ärztl. zts.*, No. 15, 1887; *V. u. H. Jahresb.*, i. 269, 1887.

<sup>2</sup> *Op. cit.*, p. 11.

<sup>3</sup> "Address to Section of Anatomy and Physiology," *Brit. Med. Jour.*, p. 346, August 18, 1888.

<sup>4</sup> "Teratology, Speculative and Causal," *Mem. and Memo. in Anat.*, p. 128.

<sup>5</sup> Ahlfeld, *ut infra*.

<sup>6</sup> *Missbild. des Menschen*, vol. i. s. 9, Leipzig, 1880.

<sup>7</sup> *Dub. Jour. Med. Sci.*, N.S., vol. xxxiii. p. 464.

from errors of quantity, of quality, and of distribution. The quantity may be in excess and the quality good, giving rise to a double monster, more or less perfect according to the amount of excess; varying from the supernumerary fingers to the parasite and the perfect double monster."

Before proceeding any further in quest of a cause, it may be well to inquire what produces segmentation in the normal ovum. That the power lies in the interior of the ovum, and that division is not influenced by external causes, is the teaching of Roux:—"The impregnated ovum bears within itself all the necessary powers for normal development," and this view is endorsed by Weissmann.<sup>1</sup> In cases of sexual generation at least, then, it must be sought in the action of the male on the female pronucleus. This influence has been compared to the effect of a spark upon gunpowder leading to its explosion. If, however, we follow the view which Weissmann has expounded in his various papers, that "the physiological values of the sperm cell and the ovum are equal, that they are to one another as 1:1," the simile and the theory to which it refers cease to be strictly correct. The cause of the division, according to the author just quoted, is the sudden increase of the quantity of the nucleus by copulation with the sperm cell. "The increase of the quantity of the nucleus gives the impulse to division, to which the predisposition previously existed."<sup>2</sup> Excess of nuclear material, nucleoplasm, or to be more correct, "germ-plasma," on this view is the cause of normal division. It may now be asked, turning to abnormal division, whether there is any direction in which such extra amount of germ-plasma may be found, which might permit or favour the occurrence of a fission of multiplication.

There are, I think, several ways in which such excess may be possibly explained.

It is needless to give any account of the well-known facts concerning the extrusion of the polar bodies; it will suffice to allude particularly to Weissmann's observations,<sup>3</sup> now fully confirmed, that in parthenogenetic ova only one such body is extruded, whilst in those which are to be sexually developed,

<sup>1</sup> *Die Continuität des Keimplasma's*, Jena, 1885, p. 17.

<sup>2</sup> *Op. cit.*, p. 98.

<sup>3</sup> *Ueb. die Zahl des Richtungskörper*, Jena, 1887.



two or possibly more are ejected. With the explanation which he gives as to the significance of these two bodies, we are not particularly concerned, yet it may be noted that, even on his own hypothesis, the second consists of true, unaltered germ-plasma, fit for fertilisation and development. In the retention of this, I would suggest, we have one possible cause of the excess of germ-plasma which may lead to the production of duplicity. Whether the nucleus remains single, is fertilised by a single spermatozoon, and then divides into two parts before true segmentation commences, or whether division, complete or partial, takes place with subsequent fertilisation by two spermatozoa, is an open question. In this connection some observations of the Hertwigs<sup>1</sup> are of importance;—"In ova with germinal vesicles, when a spermatozoon enters, there is no change, and no reaction on the part of the protoplasm of the ovum; if the polar spindle has been formed, the heads of the spermatozoa remain unaltered, but a weak protoplasmic streaming occurs. Only after the formation of the first polar body exchange of substance between sperm-cell and germ-plasma takes place, but without the formation of a looped figure (*faserige Umbildung*).” At the first blush this appears to make against the view just put forward, but it must be noted—first, that a certain effect is possible even in these cases upon the female pronucleus, yet retaining the germ-plasma of the second polar body; and secondly, and this is of great weight, the Hertwigs’ own remark (ss. 155, 156), that out of thousands of over-fertilised eggs, only two double larvæ were observed, and their surmise that as no double malformations are known to exist among Echinoderms, which formed the object of their study, these forms may be unfavourable for the production of such monstrosities. One is, I think, inclined to believe that all animals with larval stages would be much less favourable for the production of double monstrosities than those without. Before leaving this part of the subject, it may be mentioned that in plants a process similar to the extrusion of the polar bodies takes place. My colleague, Professor Hillhouse, has been good enough to call my attention to observations of Strasburger<sup>2</sup> on Polyembryony,

<sup>1</sup> *Ueb. den Befruchtungs. u. Theilungsvorgang des thierischen Eies*, s. 147, Jena, 1887.

<sup>2</sup> Goebel, *op. cit.*, p. 401.

which bear a certain resemblance to the occurrences which I have supposed as taking place in the ovum which is to develop towards duplicity, but whether this similarity is real or only apparent I do not feel competent to decide.

Passing to a second possibility, there are indications that the factor at fault may be the spermatozoon. The researches of E. van Beneden and Ch. Jolin, as also of Blomfield,<sup>1</sup> seem to show that the spermatozoid gets rid of a portion of its substance (seminal granule) before fecundation takes place. Whether in this way true *reduction* takes place, or whether, as Weissmann<sup>2</sup> suggests, it is effected by the equal division of a cell, each half of which remains as a spermatozoon, we have in either case a means by which an excessive amount of formative material may be retained in the male germ and carried into the female. One observation by Cutter,<sup>3</sup> of spermatozoa with two heads may be mentioned as possibly bearing on this point. Some such occurrence would assist in explaining cases, such as the following, where the male element was obviously the factor producing partial duplication. In this case,<sup>4</sup> the calves affected were borne by seven cows, during the course of a year and a half, the whole herd amounting to forty, the remainder producing normal offspring. Only one of the weaker cows was a primipara, the other six having all previously borne healthy calves. The malformations, which consisted in each case in the existence of a second external ear behind the normal one with a double hyoid bone, commenced after the use of an apparently perfectly healthy bull. When his use was discontinued, these cows bore normal calves.

There yet remains a third possibility, which has been adverted to by several writers, that the excess of material may be due to the entrance into the ovum of two or more spermatozoa. That the normal occurrence is for fertilisation to take place by one spermatozoon, and that the ovum possesses some power by which the entrance of superfluous spermatozoa

<sup>1</sup> For references see M'Kendrick, *Text-Book of Physiology*, vol i. 231; cf. also Haddon, *Embryology*, p. 11.

<sup>2</sup> *Ueb. die Zahl des Richtungskörper*, p. 58.

<sup>3</sup> Gaillard's Med. Jour., *Lond. Med. Rev.*, xiii. 291.

<sup>4</sup> "Rost. Veb. eine Reihe von Kalbsmissgeb.," *Sächs. Ber.*, 133, 1878; *V. u. H. Jahresb.*, i. 605, 1878.

is prevented, has been established by the Hertwigs,<sup>1</sup> yet their researches show that polyspermia may occur, and notably in immature ova. As already noted, this fact has been urged as the cause of duplicity by several writers. Thus Born<sup>2</sup> considers it probable that the entrance of two spermatozoa into the ovum of the frog may lead to double malformations, but not, so far as is known, to twins. Fol,<sup>3</sup> offers a similar suggestion, and states also that "when spermatozoa in excess enter an ovum, they may, under the nourishing influence of the cell body, become centres of attraction and form an amphiasier, *i.e.*, the first figure in the direction of nuclear and cell division. They cannot control the whole cell body and bring it to division, but they exercise a certain power, and do this at the expense of the cell substance." Strasburger has called this "partial parthenogenesis." The reason why the process thus described does not go further is, according to Weissmann, that the supply of germ plasma is insufficient for that purpose. Reverting here to an earlier portion of this paper, it may be asked whether the retention of the whole, or a part of the second polar body, might not supply the lacking material. A similar suggestion as to the result of polyspermia to that of Born has been offered by Marchand<sup>4</sup> and Ziegler.<sup>5</sup> In any of these ways, then, it seems possible that an excess of the true formative material, the germ-plasma, may exist in the oosperm, and lead by its presence to the production of duplicity.

If a sufficient amount be retained and fission is complete, homologous twins results; if the fission be incomplete, then one or other form of true double monster, the amount and site of the connection being due to the amount and direction of the primary lines of fission. Should a smaller amount be present, then, according to the site of its distribution will be the kind of minor duplicity which the foetus will present.

<sup>1</sup> *Op. cit.*, s. 136; *Bastardbefruchtung.*, s. 45, Jena, 1885; *Lehrbuch der Entwic. Zwe. Aufl.*, s. 35.

<sup>2</sup> Quoted by Weissmann, *Richtungskörper.*, s. 71.

<sup>3</sup> For the second statement Weissmann, *Continuität*, s. 107, is responsible; for the first, Hertwig, *Befruchtungs.*, s. 1.

<sup>4</sup> Ziegler, *General Pathology*, Eng. Trans., p. 24, quoting from *Realencyclopädie d. ges. Heilkunde.*

<sup>5</sup> So states Eimer, *Entstehung der Arten*, s. 201, Jena, 1888, but gives no reference.

Two questions remain for consideration, which can only here be mentioned, since their detailed examination would cause this paper to grow to a size too great. These are, firstly, with regard to the so-called parasites, are such forms due to unequal fission, the smaller half producing the parasite, the larger the autosite, or is the disproportion caused by the blighting effect of the larger and more fortunate twin upon its less successful partner? Secondly, what relation is there between the excess of material which leads to the production of giants, of unilateral congenital hypertrophy of the body, or of a part, such as the face, an extremity, or some of the digits, and that excess of material which it has been suggested in this paper causes the formation of some species of double monstrosity? These are questions which will require consideration on some future occasion.

